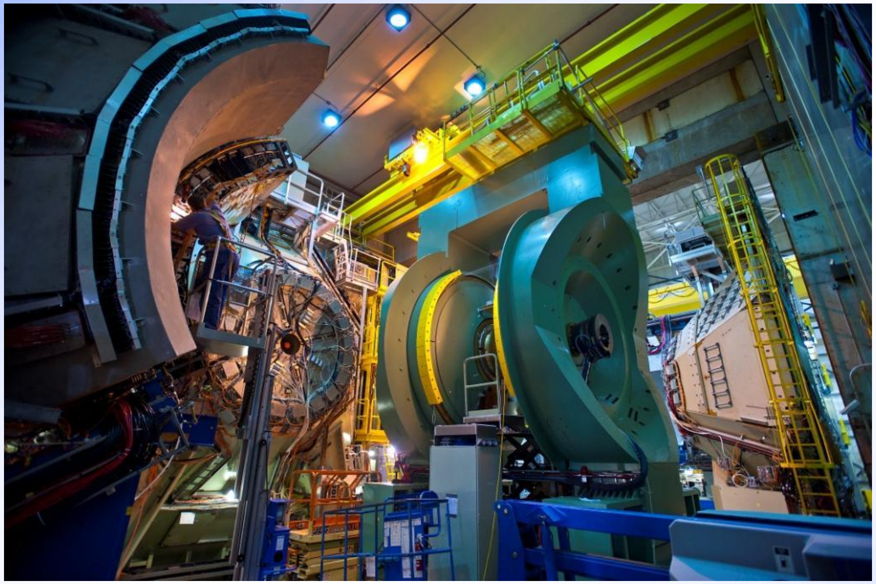
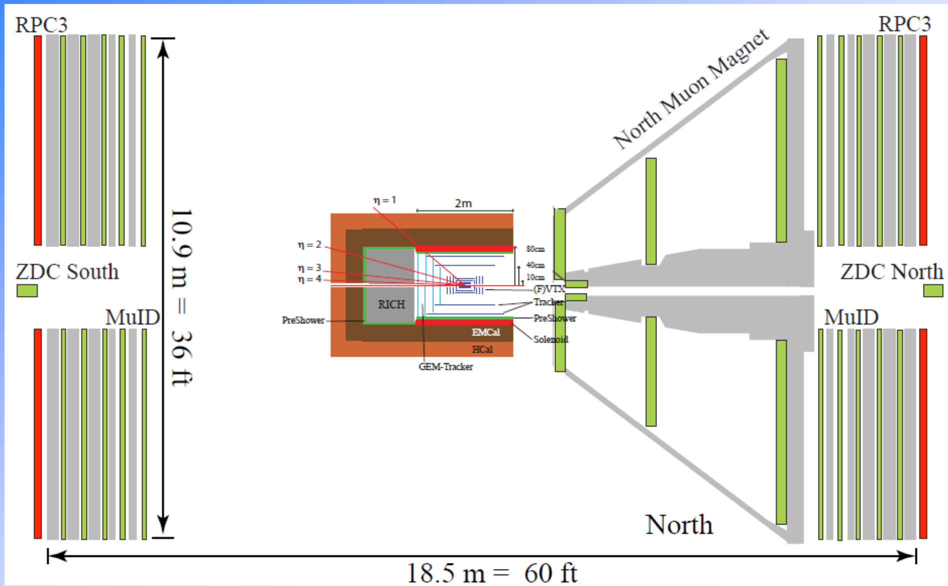
PHENIX Current and Future R&D

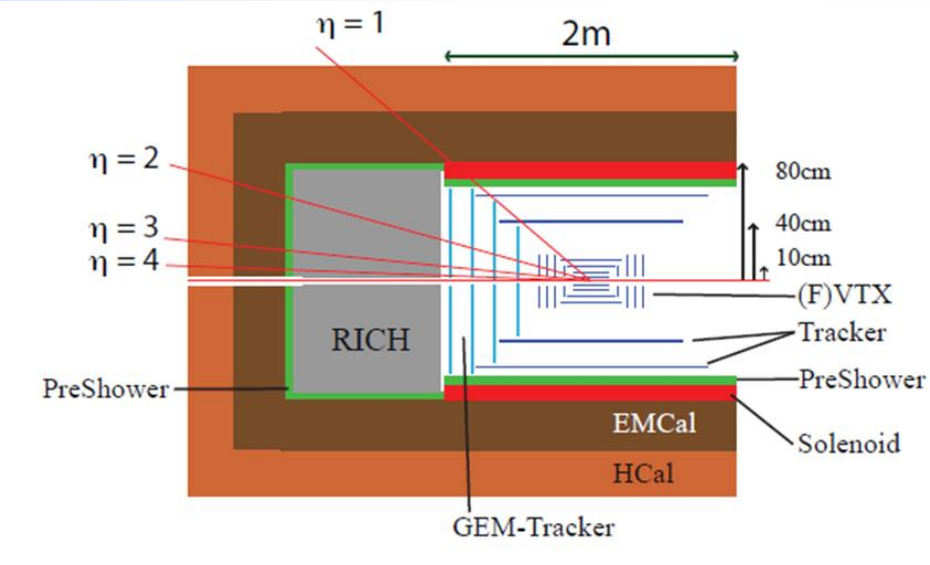
Upgrades to PHENIX to be Completed and Operational over the Next 3 to 8 Years



- **Near Term Upgrade to Existing Detector**
  - **Preshower detector in front of existing PbWO4 calorimeter 3.0 < η < 3.8**
  - **DAQ bandwidth upgrade**
- **Longer Term sPHENIX Upgrade**
  - **Expansion of existing Si Tracking**
  - **PreShower**
  - **EMCal**
  - **Hadron Cal**
  - **Forward Tracking (GEM or Micro Megas)**
  - **A variety of PID (Fast TOF, MuID, RICH/DIRC, TRD)**

sPHENIX





- **High Field solenoid**
- **Compact Tracking**
- **HCal covering the full azimuth**
- **Greatly expanded forward rapidity capability**
- **Compatible with a natural evolution to an EIC detector**

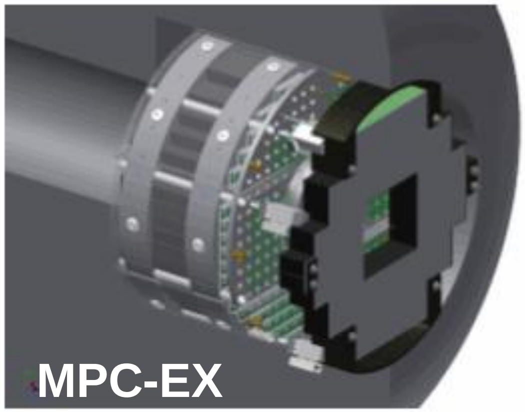
Several Types of R&D

- **New or emerging technologies**
  - Si-tungsten Preshower
  - Fast TOF (10-20 psec resolution)
  - Tungsten -fiber EMCal w/ SiPM readout
- **Customizing of existing technologies for application in PHENIX**
  - HCal (Fe, Pb or Cu Tile or SpaCal)
  - GEMs for PHENIX specific geometries
  - Multi-radiator Cherenkov (RICH , DIRC…)
  - Development of electronics for PHENIX-specific DAQ/Trigger applications
- **Experience using mature technologies**
  - Si strips for barrel tracker

PreShower R&D

PreShower in both Near Term and Long Term Upgrades

MPC-EX is a tungsten-Si preshower designed to sit in front of existing PbWO4 calorimeter to separate close showers for photon/π0 separation and jet angle measurements.



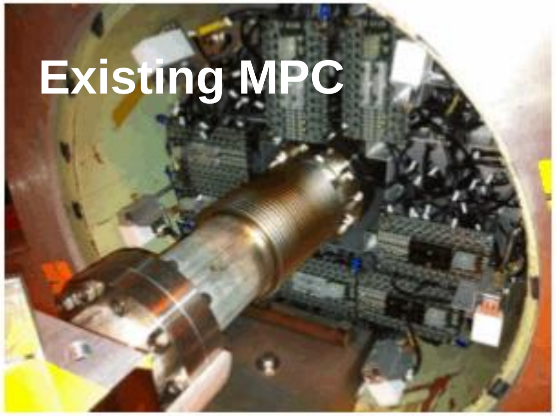


Figure 2.1: A beam view of the North Muon Piston with MPC installed. Signal cables removed.

Table 2.1: MPC-EX Preshower design features. All counts are for a single unit.

Parameter	Value	Comment
Distance from collision vertex	220 cm	
Radial coverage	$\sim$ 18 cm	
Geometrical depth	$\sim$ 5 cm	
Absorber	W (2mm plates)	$\sim$0.5 X_0 or $\sim$2% L_{abs}
Readout	Si pixels ($1.8\times15\,mm^2$)	
Sensors	$62 \times 62\,mm^2$	192 ($1.8 \times 15\,mm^2$ minipix-els)
Pixel count	24576	
SVX4's	384	

Calorimetry R&D

Design Options for the sPHENIX EMCAL

Requirements:

- Compact ("small" Moliere radius and "short" radiation length)
- Projective
- Hermetic
- Readout works in a magnetic field
- Low cost

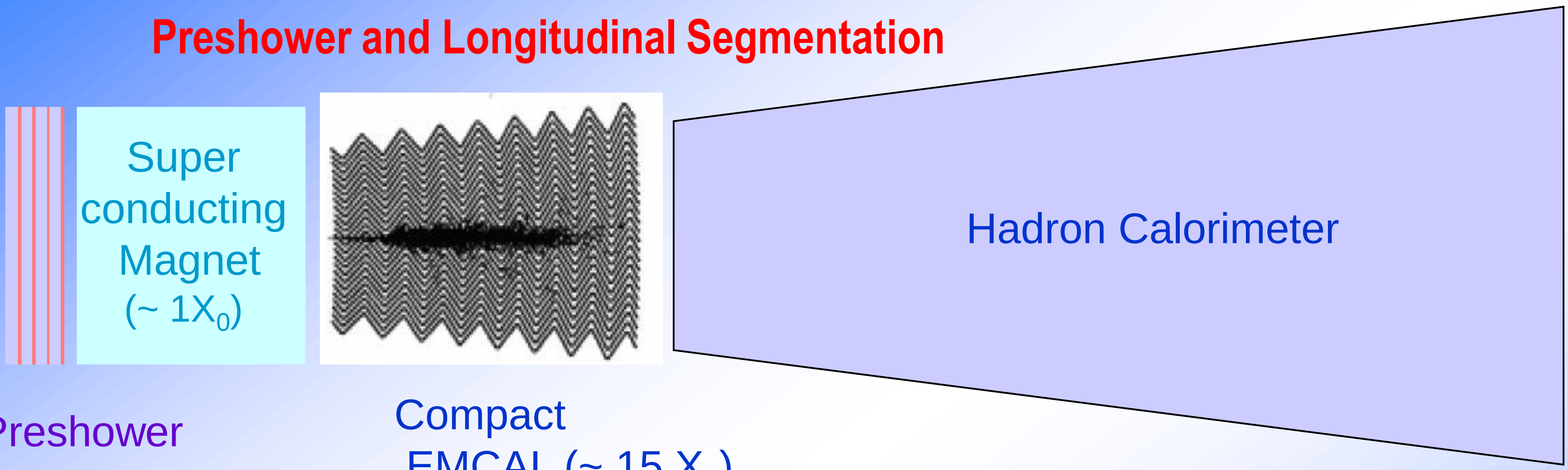
Options:

- Optical accordion
- Projective shashlik
- Scintillating fiber

Any design must include a (presumably) tungsten-silicon preshower which would sit inside the magnet

sPHENIX Calorimetry

Preshower and Longitudinal Segmentation



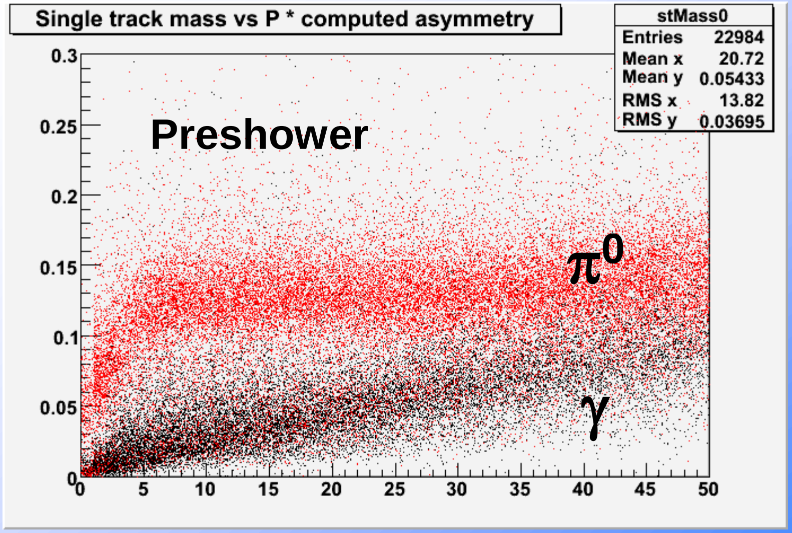
Preshower

Compact EMCAL ($\sim 15\ X_0$)

- $\sim$ 3-4 X_0
- Si–W with ~ 2mm W plates
- Spatial resolution ~ 500 μm

Longitudinal segmentation required for:

- γ/π^0 separation for single γ and jet measurements up to $p_T \sim 40$ GeV/c
- e/π separation ($\sim 10^{-3}$) for measuring J/Ψ's and Υ's

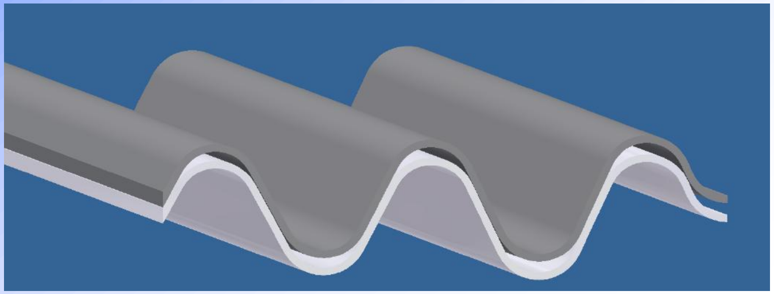


E. Kistenev

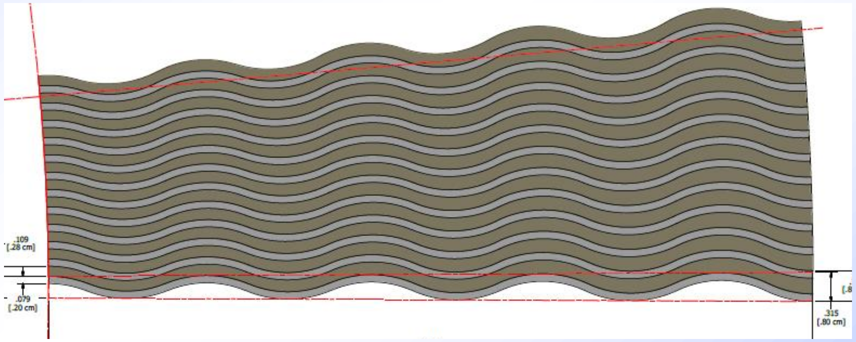
Optical According

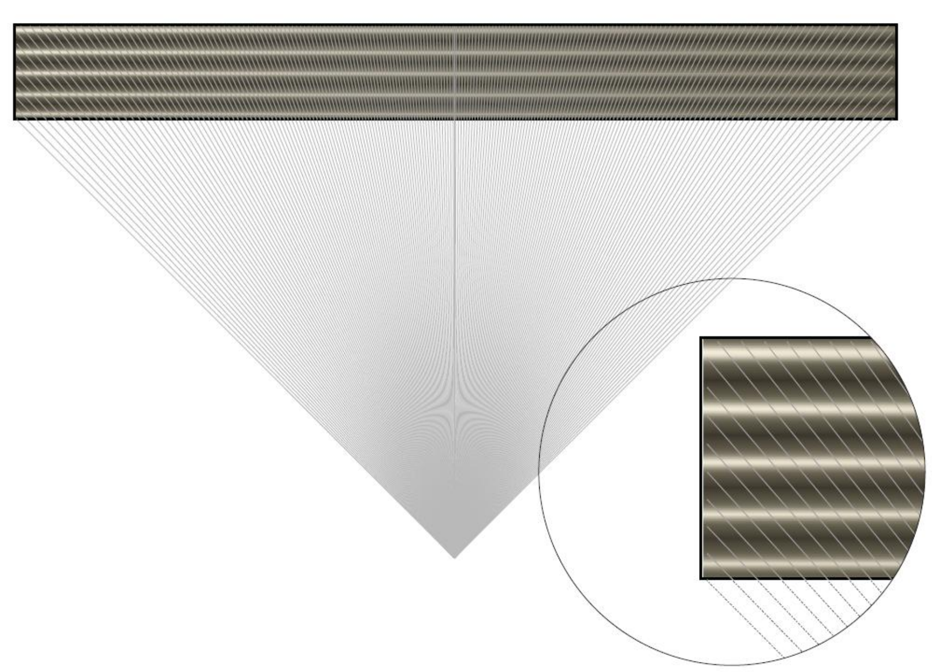
Accordion design similar to ATLAS Liquid Argon Calorimeter

- Optical readout with either scintillating fibers or scintillating plates with embedded wavelength shifting fibers
- Fibers read out with SiPMs o APDs



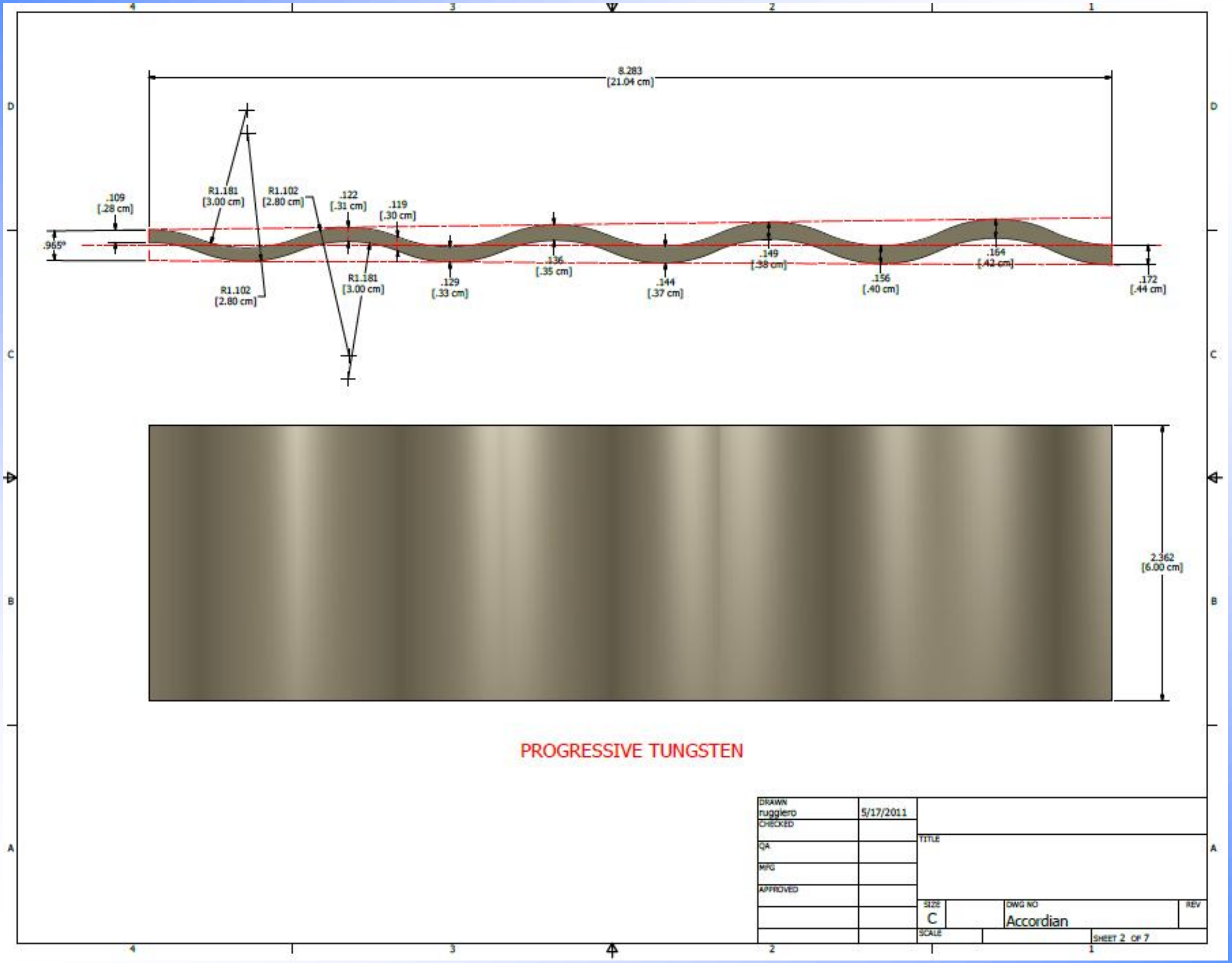
Question:
How to make it hermetic and projective



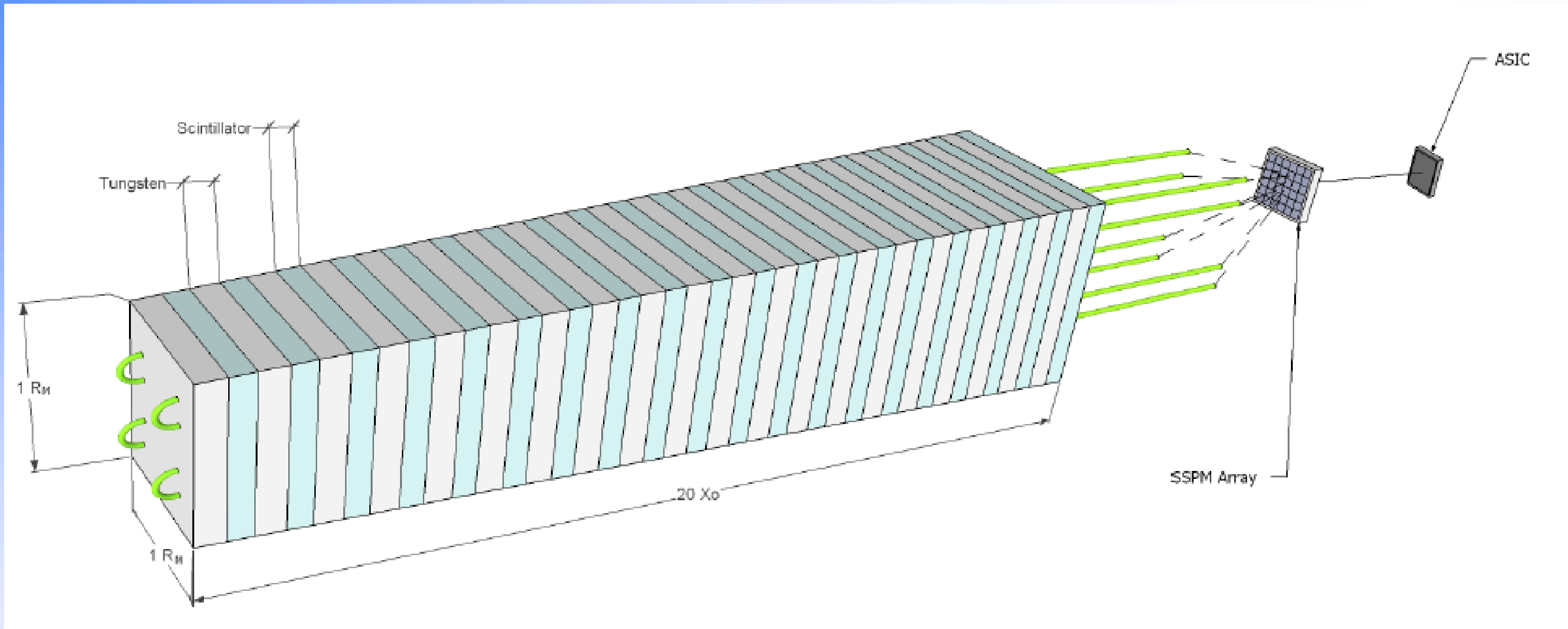


- Volume increases with radius
- Scintillator thickness doesn't increase with radius, so either tungsten thickness must increase or the amplitude of the oscillation must increase, or both
- Plate thickness cannot be totally uniform due to the undulations
- Small amplitude oscillations minimize both of these problems

Progressively Tapered Accordion Plate



Projective Shashlik



- Size of absorber and scintillator plates would both increase as a function of depth
- Small size improves light collection compared with our current shashlik
- Again, challenge is to collect all the light onto a SiPM or APD, but there are fewer fibers compared to the accordion

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Sci-Fi Design Study

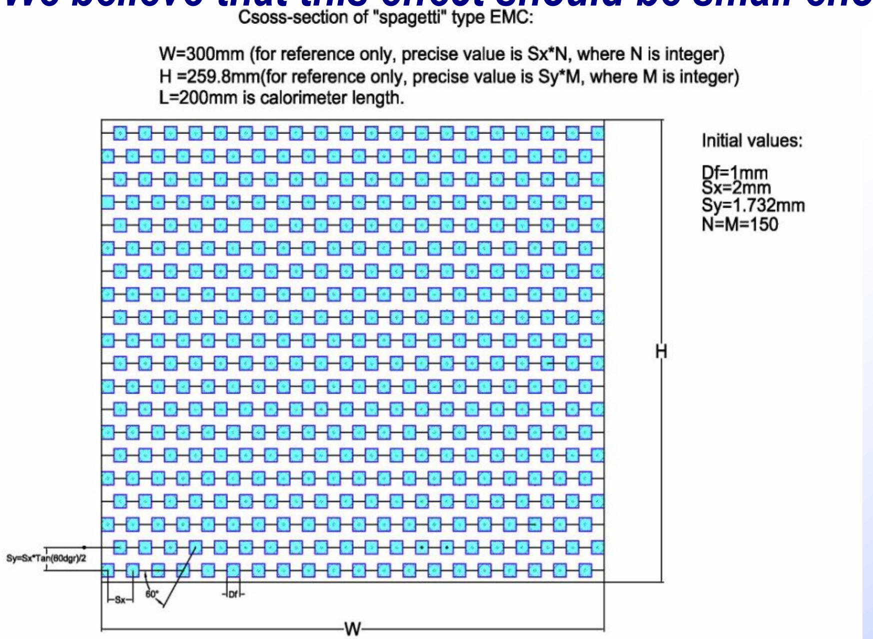
Two types of Scintillator+absorber structures have been simulated:

1) "spaghetti" with maximal geometrical sampling uniformity (left figure);

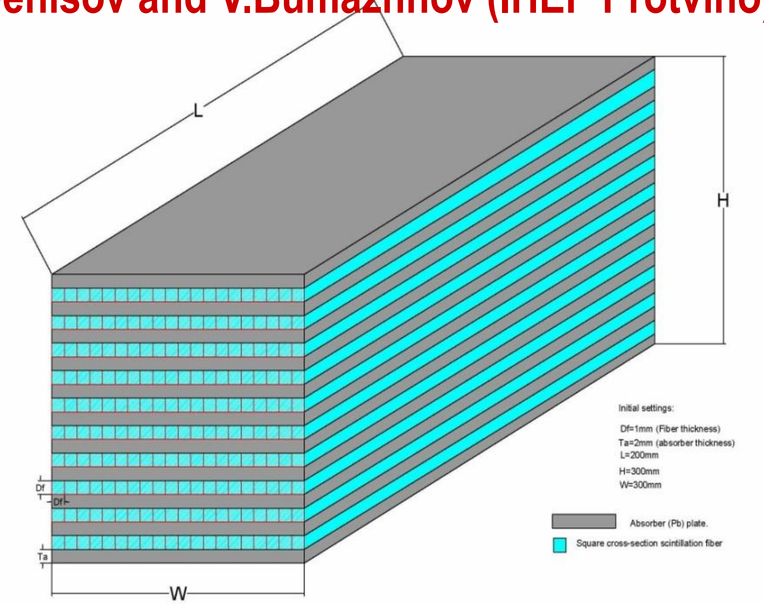
2)"slice" type for simplest mechanical treatment (right figure);

W and Pb absorbers

Simulations have been performed for calorimeter modules with cross-section of 300mm x 300mm and length of absorber of 200 mm(along of electron beam). The volume scintillator/absorber ratio is of about 30% for both cases. ***Geometry modification to take into account projective geometry requirements has not been implemented in this simulation yet. We believe that this effect should be small enough.***

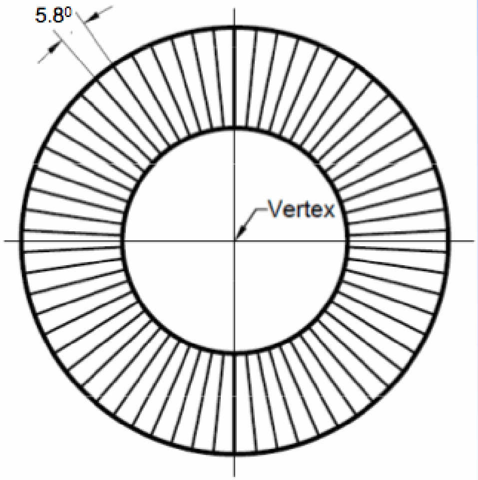


A.Denisov and V.Bumazhnov (IHEP Protvino)

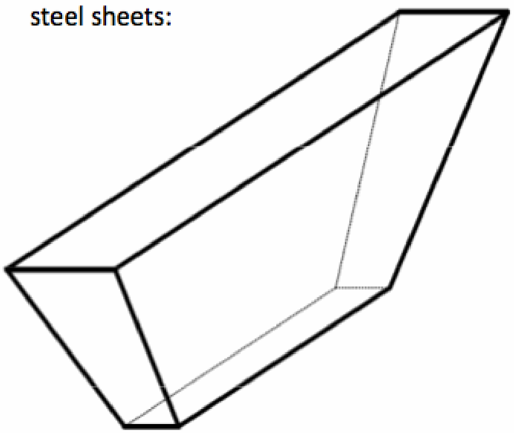


HCal Tile Calorimeter R&D

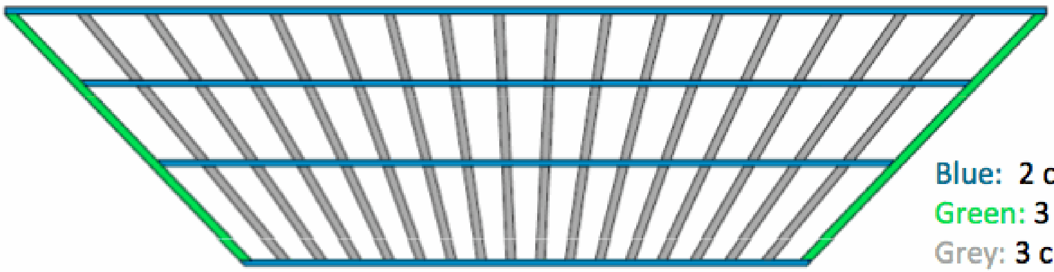
HCal is built from 62 sectors



Every sector is a case made of steel sheets:



Along the beamline:

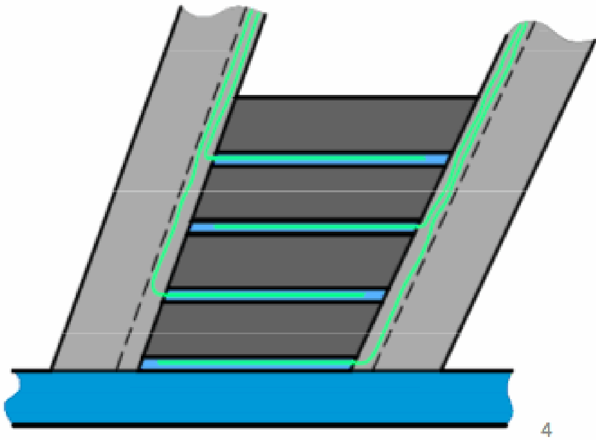


Blue: 2 cm thick steel
Green: 3 cm thick steel
Grey: 3 cm thick steel

Conduits are milled in grey and green sheets (for readout fibers, etc.).

Each created cell is filled with stacks of scintillator tiles and Pb or steel plates such that they are all parallel to the beamline.

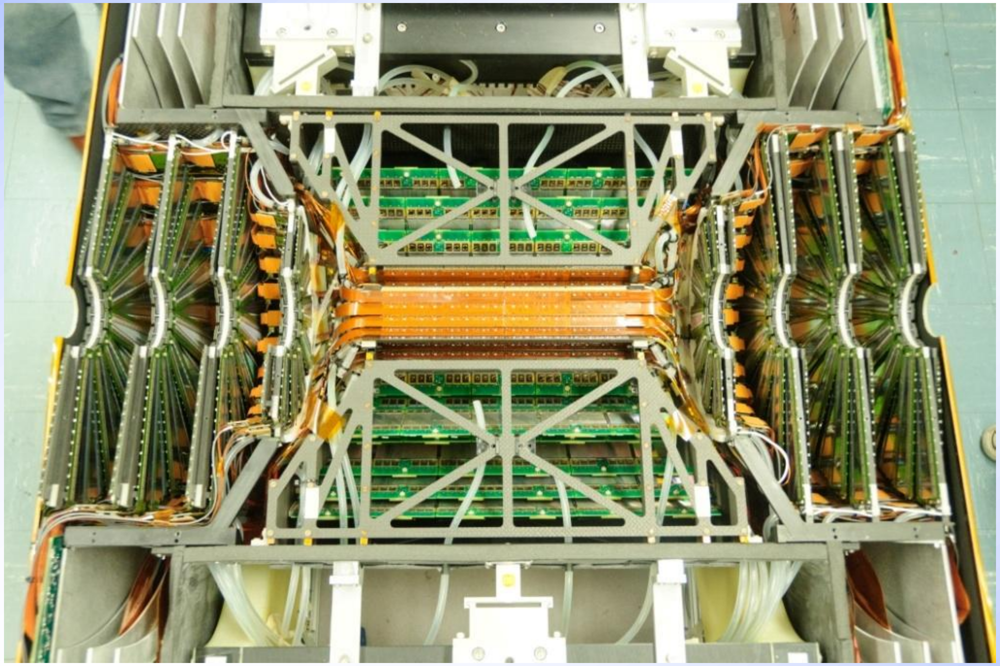
Wave-length shifting fibers are glued in grooves made in the tiles and run through the conduits toward outer radius of the HCal to be read out by photomultiplier tubes.

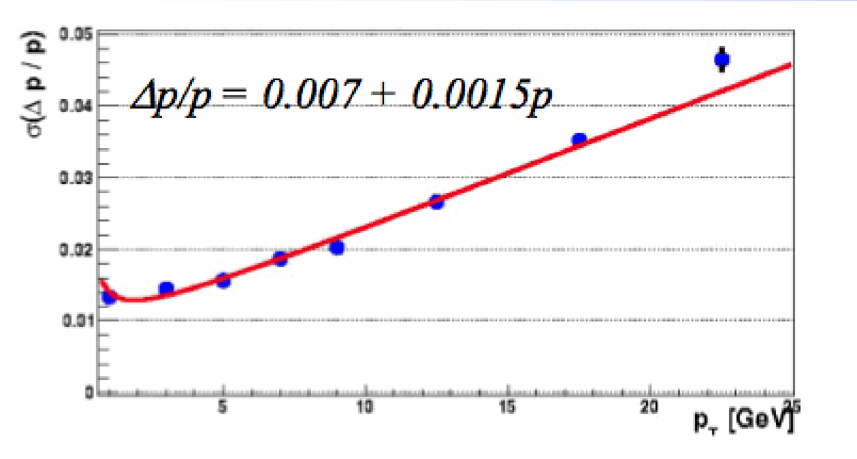


Tracking R&D

Si Tracking in sPHENIX

- **Existing Si Vertex detector has 4 layers (~10% L_rad) in the central barrel and 4 layers per endcaps**
- **sPHENIX envisions 2 (maybe 3) additional Si strip layers in the barrel which together with a magnet upgrade obtains to the desired momentum resolution**
  - **Total of 6 (maybe 7) layers**
  - **For comparison ATLAS has 7 layers of Si (40% L_rad) and CMS has 11 layers**

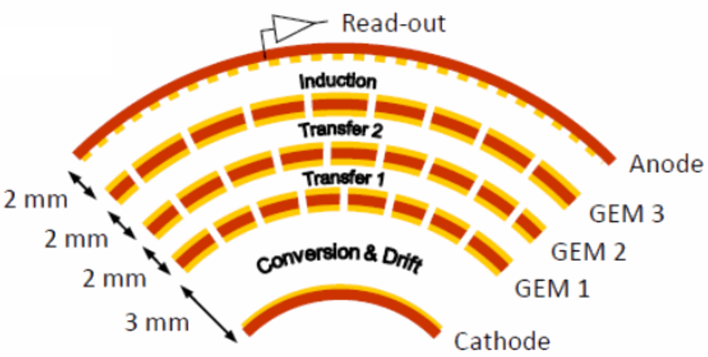


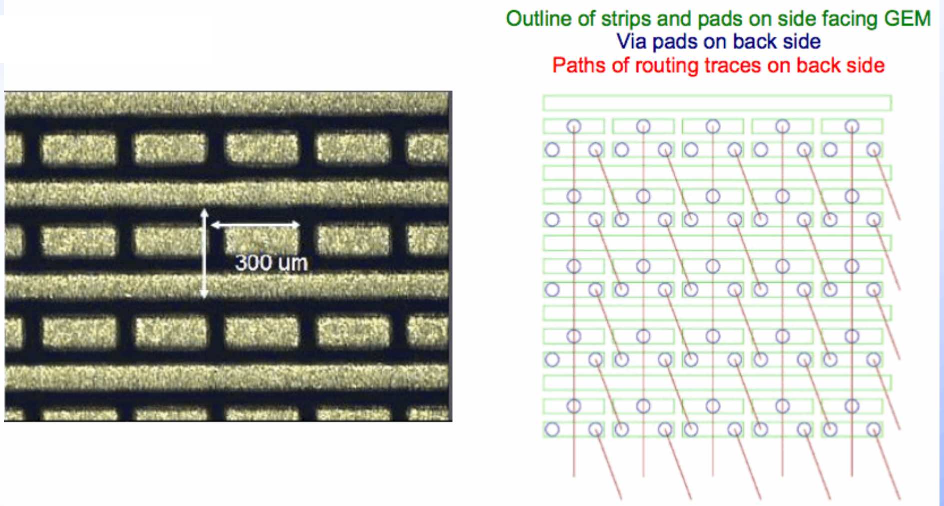


GEM R&D

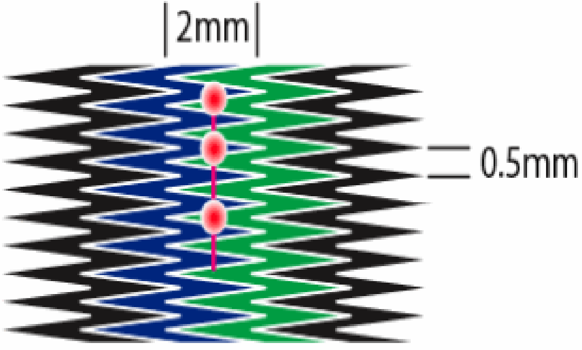
Event though PHENIX has significant experience with GEMs on PHENIX our upgrade plans require different geometries (cylindrical or large flat planar) in addition to different cathode readout configurations

Cylindrical GEM readout structure





3D readout for higher track multiplicity capability



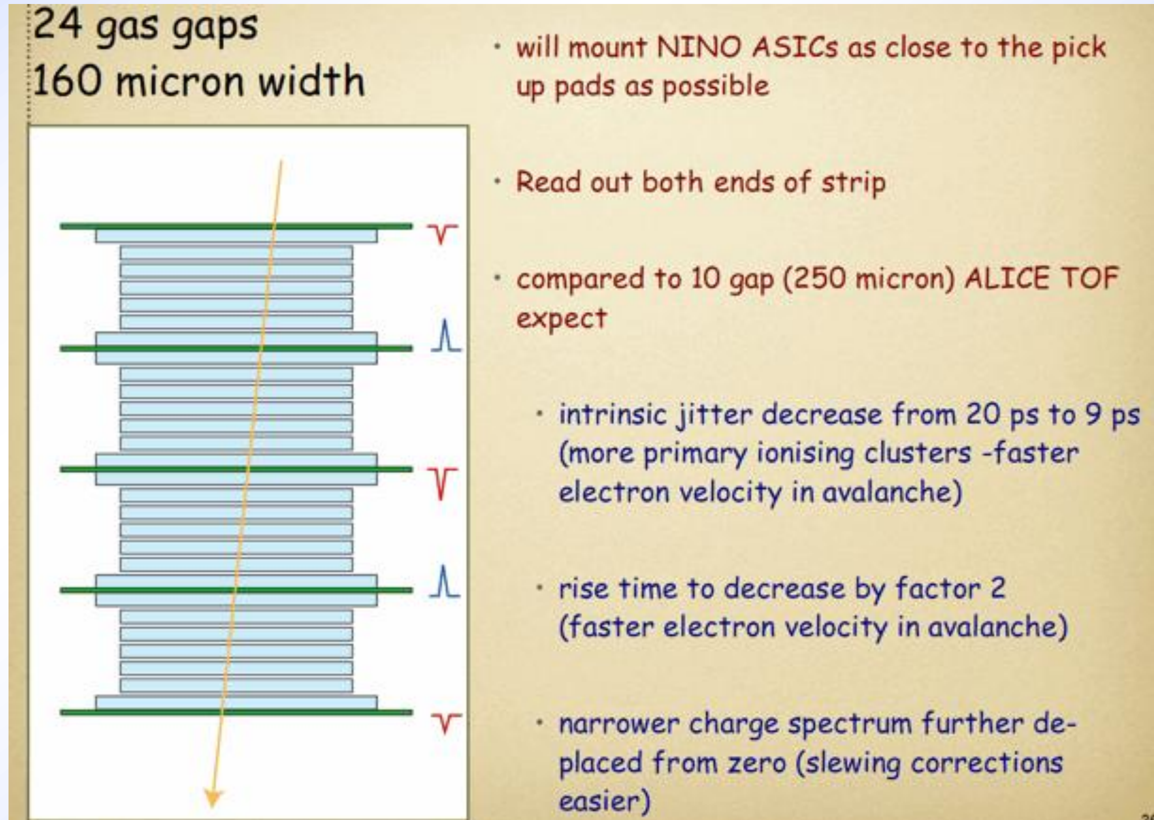
Chevron style pad readout

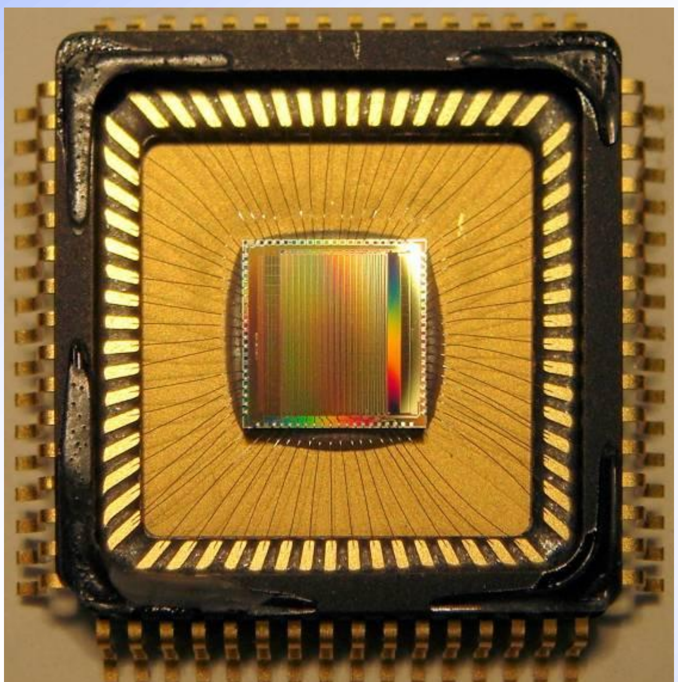
Particle ID R&D

TOF Options

Recent technology developments make TOF w/ resolutions of 10-20 ps practical within the next few years

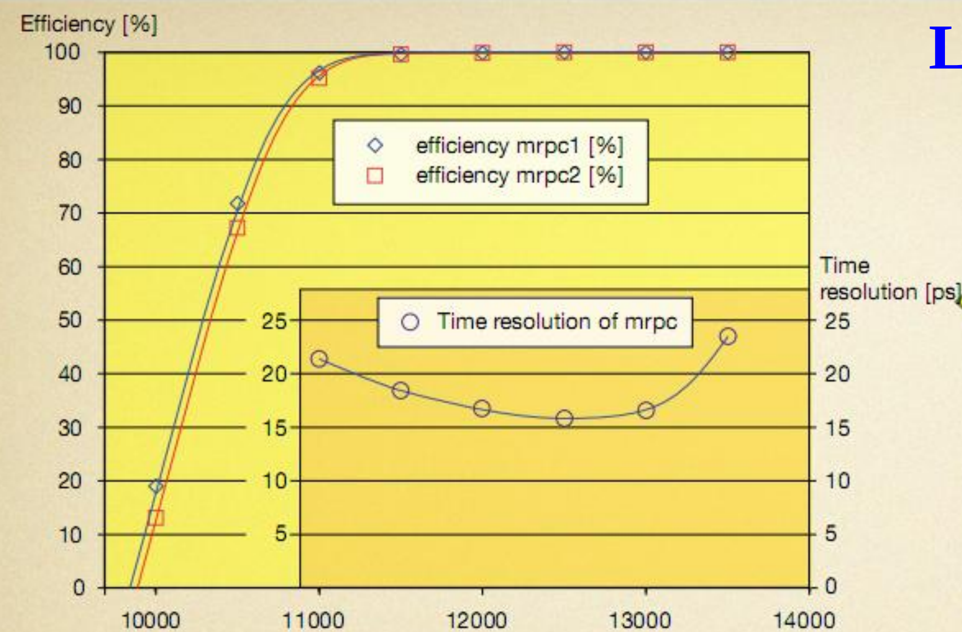
- **Advanced mRPCs**
- **Micro channel plates**
- **ASICs for fast timing**

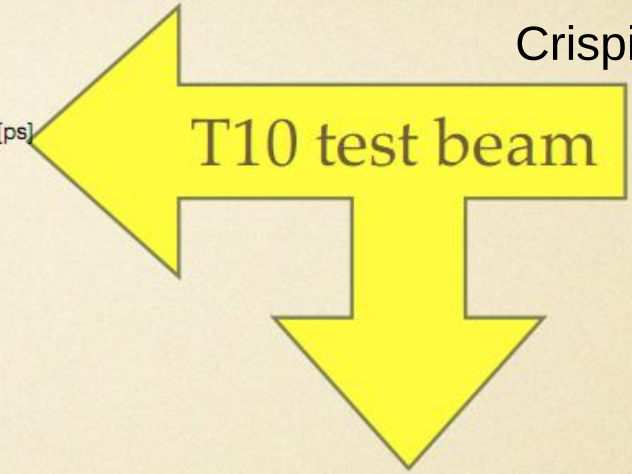


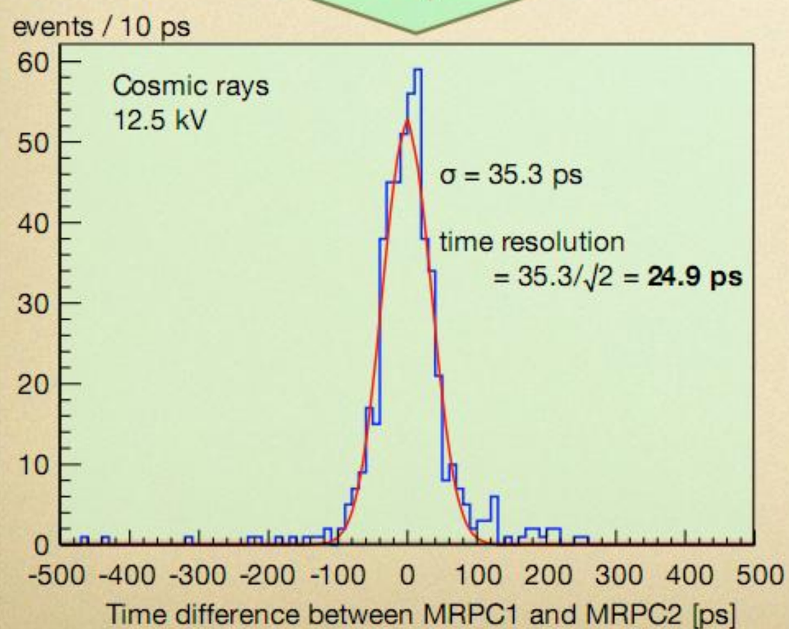


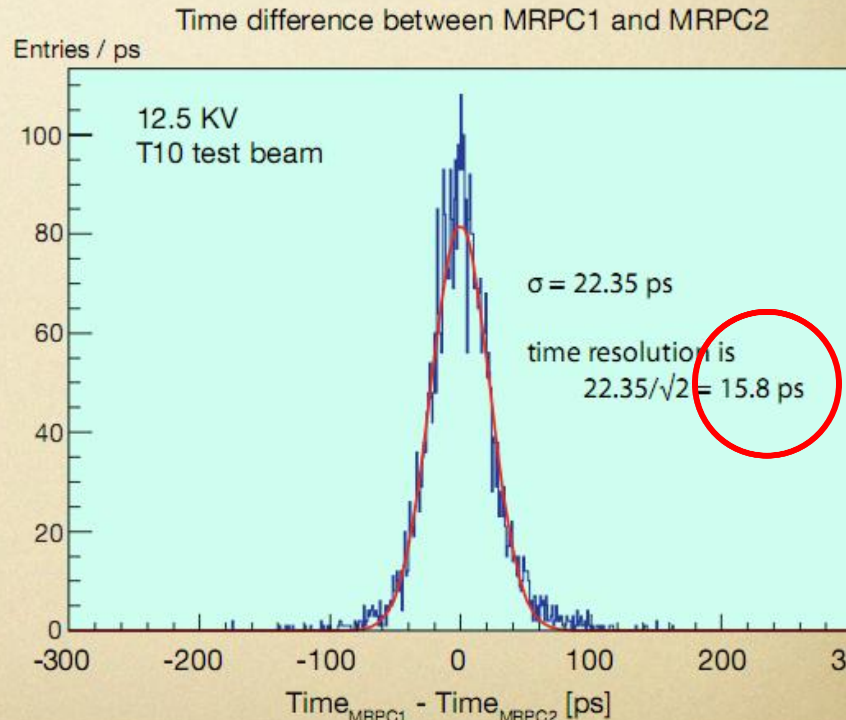
Latest Generation mRPC Results *from Mickey C*

Crispin Williams







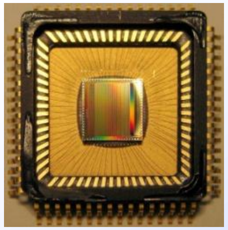


Fast TOF Electronics Choices *from Mickey C*

Cheaper

Faster

PHENIX BBC (30 ps,>$10K/ch)
PHENIX TOF (30 ps, $1K/ch)

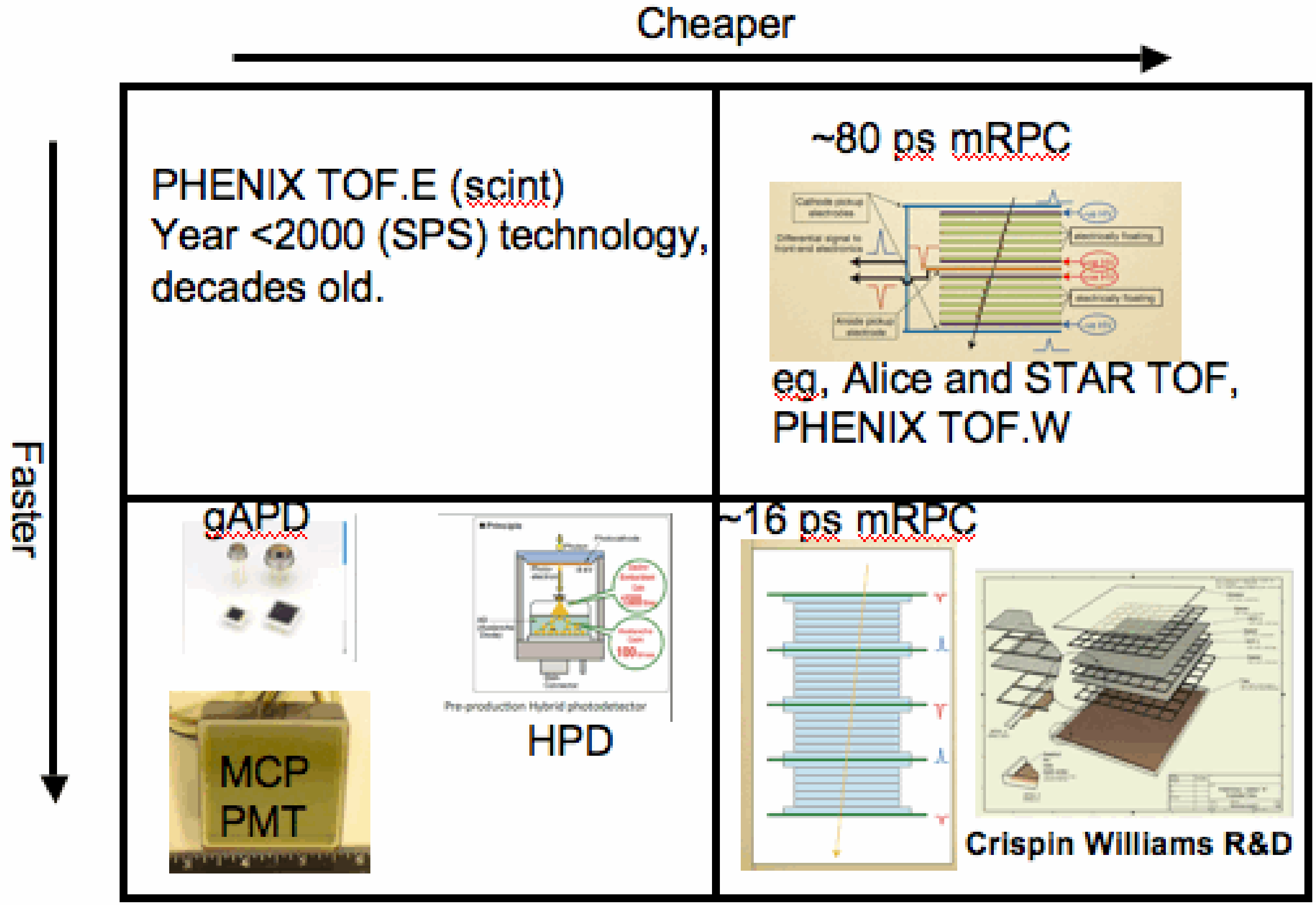


DRS4
(ASIC
$10/ch)

HBD FEE
(~$200/ch)

HBD FEE could be developed up very fast (needs test of time stretcher)
DRS4 and other ASICS could be developed, but would add year or two

FAST TOF Detector Choices *from Mickey C*



- Fast electronics (major technical hurdle) more or less solved
- For small area, MCP-PMT's provide high performance (10ps) but high cost
- Recent advances in mRPC seem to achieve 16 ps mRPC (low cost, large area detector)
- Tsukuba, BNL (and possibly others), R&D project to produce 16 ps mRPC prototypes

Muon Detector Options

Limited R&D Needed

Possible low cost Muon Detector: 2 layers of RPCs behind the HCal

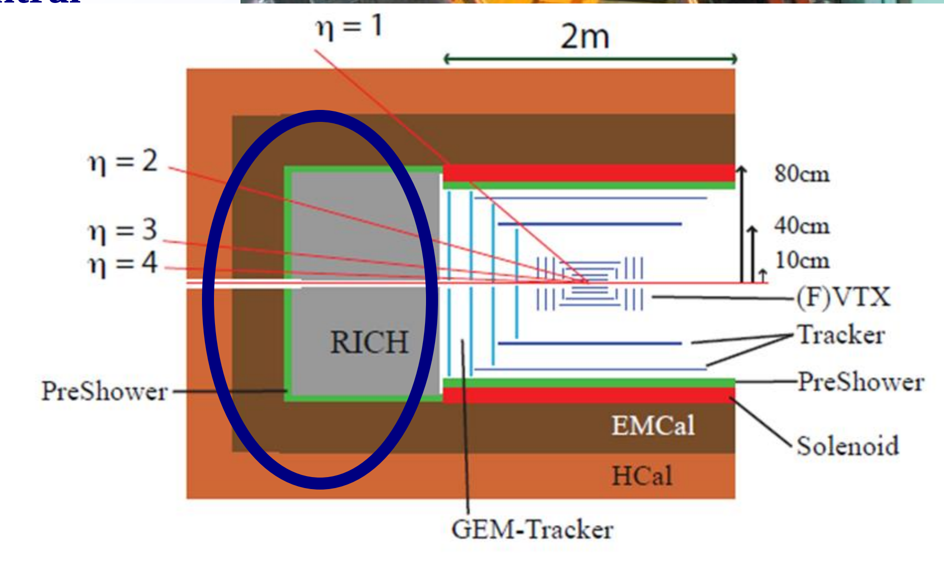
- **2 layers of RPCs at r=4 m, z = 5m is ~250 m^2 of RPCs.**
- **Similar to St3 N&S RPCs ~160 m^2**

Other technology options:

- **Proportional Drift tubes**
- **Iarocci tubes**

Cherenkov PID R&D

- **HBD-type detector for e/hadron in central barrel**
  - **Can it be made to work in a magnetic field?**
- **Multi-radiator Cherenkov in forward arm**
  - **Aerogel+heavy freon**
  - **Gas + liquid radiator+ UV transparent windows**
  - **Readout ALICE HMPID style?**
  - **Can something like this work in the central barrel?**
  - **How compact can it be?**
  - **Is it compatible with a magnetic field?**



Some EIC R&D underway. No PHENIX-specific R&D yet

HMPID Detector Description

from Klaus D

• The ALICE-HMPID (High Momentum Particle Identification Detector) performs charged particle track-by-track identification by means of the measurement of the emission angle of Cherenkov radiation and of the momentum information provided by the tracking devices.

• It consists of seven identical proximity focusing RICH (Ring Imaging Cherenkov) counters.

RADIATOR

15 mm liquid C_6F_{14},
n ~ 1.2989 @ 175nm, $\beta_{th} = 0.77$

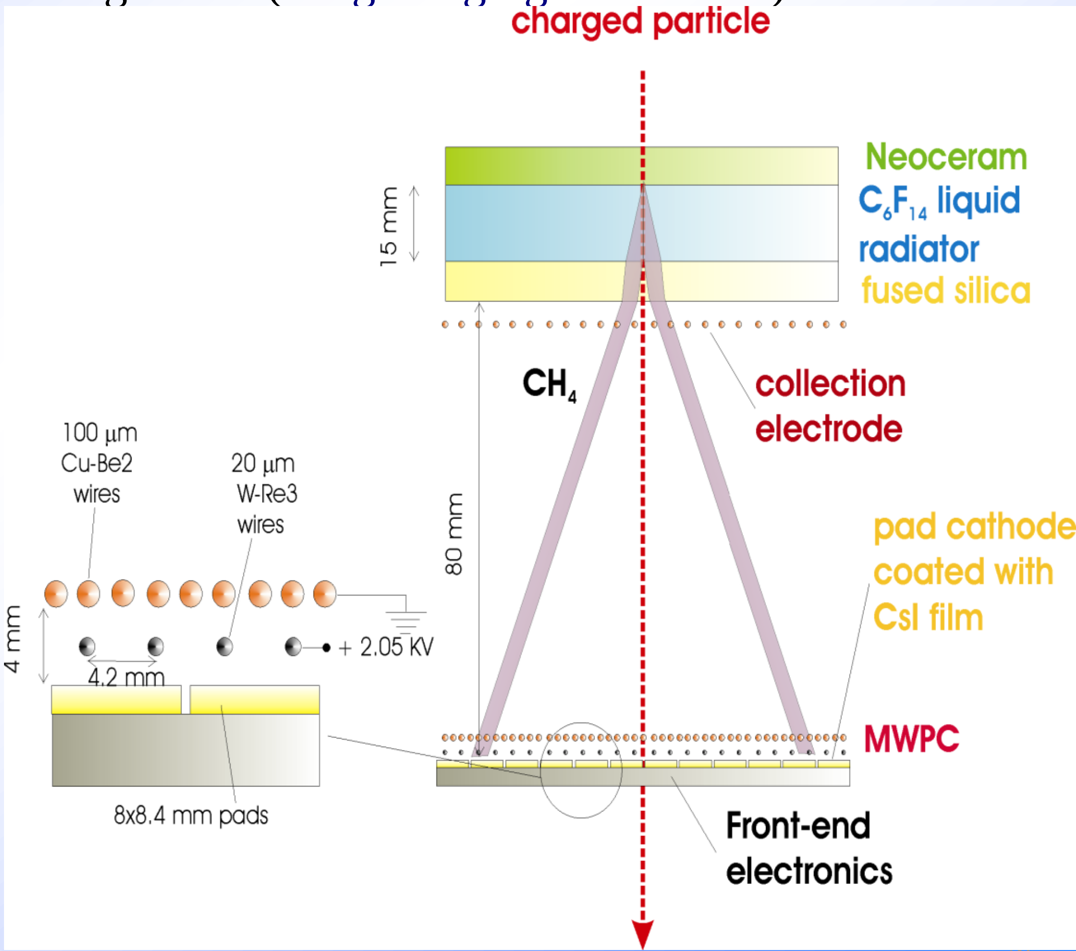
PHOTON CONVERTER

Reflective layer of CsI
QE ~ 25% @ 175 nm.
The largest scale (11 m²) application of CsI photo-cathodes in HE/HI-P!

PHOTOELECTRON DETECTOR

- MWPC with CH_4 at atmospheric pressure (4 mm gap) HV = 2050 V.

- Analogue pad readout



Other PID Technologies

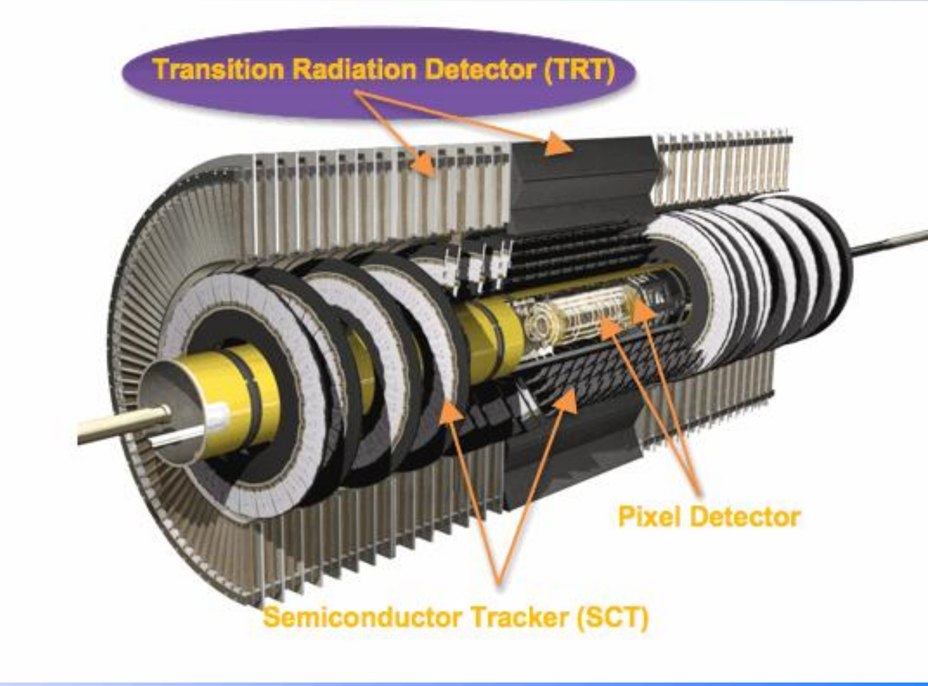
dE/dx

- Combine with TOF for e/hadron and pi/K/p in central barrel
- What is the minimum thickness (20 cm?)
  - The STAR TPC uses 2 m gas for its dE/dx measurement
- What kind of granularity is needed for this type of detector to operate in central HI events

TRD

- Electron/hadron separation starting at p > 2 GeV/c
- ATLAS TRT type or PHENIX TEC style i
- Could be of use in forward arm
- Good for p+p, d+A

No PHENIX specific R&D yet



Conclusion

- **The PHENIX upgrades plans, especially those that appear in the PHENIX Decadal planning document, require that a large number of R&D issues that need to be addressed prior to the start of upgrade construction**
- **R&D covers a broad range detector of topics**
  - **Calorimetry including preshowers**
  - **Si and GEM Tracking**
  - **PID (Fast TOF, Muon ID, Cherenkov…)**
- **Much of the R&D work has started but with only a couple of exceptions the PHENIX-specific work has been going on for less than one year.**
  - **One significant exception is the preshower work which is far advanced**